

Original Research

ADDITIONAL RECORDS ON BENTHIC DIATOM *Encyonema bonapartei* Heudre, C.E. Wetzel & Ector (Cymbellales, Bacillariophyceae) IN WATER BODIES OF THE UVAC SPECIAL NATURE RESERVE (SERBIA)

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Abstract

*With the rapid global decline of biodiversity in freshwater habitats, there is an increasing need to document rare taxa. The goal of this study is to report new findings on the distribution of *Encyonema bonapartei*, a rare diatom previously described only in France and Serbia. In 2024, we identified *E. bonapartei* at two additional sampling sites in the Uvac Special Nature Reserve, at reservoirs where it was not recorded in the earlier 2021 study. The values of physicochemical parameters and ecological status classes were consistent with previous research.*

Keywords: diatoms, *Encyonema bonapartei*, Uvac, distribution, rare species.

INTRODUCTION

The geographical distribution of microscopic eukaryotes is a key research topic for understanding their role in the biosphere [1]. Since the early 20th century, the ubiquity hypothesis, commonly summarised as “everything is everywhere” [2], has strongly influenced research on the biogeography of microorganisms [3,4]. The hypothesis suggests that, due to their high dispersal ability, geography may play a lesser role in shaping distribution patterns than ecological factors. However, this postulate remains controversial [5]. In the case of diatoms, although they are generally considered ubiquitous, many taxa exhibit distinct biogeographical patterns [6–8]. Rare diatom taxa are of particular interest in this context, as their limited records may reflect either specific ecological requirements and restricted distribution patterns or insufficient data on their occurrence due to limited sampling effort [9,10].

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Microscopic observations of the unique morphological features of the diatom *Encyonema bonapartei* Heudre, C.E.Wetzel & Ector noted in 2021 in samples from the Uvac Special Nature Reserve, led to its first report in the algal flora of Serbia [11]. The species was initially observed in the canals of the Great East region of France in 2014 and described by Heudre *et al.* [12]. According to existing data, *E. bonapartei* has been documented only in France and Serbia. As a rare taxon, its ecological preferences and distribution remain insufficiently understood.

The aim of this study is to highlight the expansion of *E. bonapartei* distribution in Serbia, and to characterise the community structure, ecological status, and physicochemical conditions of the sampling sites where the taxon was recorded.

MATERIALS AND METHODS

Study area

The Uvac River is located in southwest Serbia, stretching for 119 km, with three reservoirs constructed along it (Zlatar, Radoinja, and Sjenica lakes) [13]. A significant part of the river, particularly the gorge and the reservoirs, is designated as the Special Nature Reserve "Uvac". The river uniquely meanders around ten times [14] as it flows from the Pešter plateau to its confluence with the Lim River near Priboj. The survey of the Special Nature Reserve was conducted in August and October 2024. The sampling sites at the rivers Uvac, Marić, Zlošnica, Tisovica, Kladnica, Veljušnica, and Vapa, as well as the reservoirs Lake Sjenica, Lake Zlatar, and Lake Radoinja, are mainly consistent with the 2021 study [11].

Samples collection and analysis

Phytobenthos sampling was carried out in accordance with standard protocols [15]. The surfaces of five stones from the euphotic zone were scrubbed, the material was rinsed into a sampling bottle and preserved with a 4% formaldehyde solution. In the laboratory, samples were cleaned of organic matter [16]. Cleaned frustules were then mounted in Naphrax mounting resin. Permanent slides were examined using a Carl Zeiss AxioImager.M1 microscope, with an AxioCam MRc5 camera. The relative abundance of identified taxa was attained based on 400 counted valves. The indicative ecological status of the sampling sites was determined according to national laws [17], based on values of the IPS and CEE indices [19] exported from OMNIDIA software [18]. In addition to phytobenthos sampling, physicochemical parameters: temperature (T, °C), dissolved oxygen (O₂, mg/L), oxygen saturation (O₂, %), electrical conductivity (EC, µS/cm) and pH were measured using YSI's ProDSS Multiparameter Handheld Meter. Measurements of ammonium (NH₄⁺, mg/L), orthophosphate (PO₄³⁻, mg/L), nitrite (NO₂⁻, mg/L) and nitrate (NO₃⁻, mg/L) were performed using a multiparameter photometer Lovibond® MD 600.

RESULTS

Community structure

Compared with the 2021 study [11], the presence of *E. bonapartei* was confirmed in the 2024 investigation in samples from the Marić River and Lake Zlatar, and newly recorded at sampling sites on Lake Radoinja and Lake Sjenica (Table 1).

Table 1 Sampling sites where *E. bonapartei* was recorded in 2024 (+ present in sample, / absent from sample)

Sampling site	Coordinates	Sampling month	
		August	October
Marić River	N 43.520074; E 19.801116	+	/
Lake Radoinja	N 43.521818; E 19.743199	+	+
Lake Zlatar	N 43.510045; E 19.811677	/	+
Lake Sjenica	N 43.417847; E 19.927749	+	+

In the August survey, 30 taxa were identified in the Lake Radoinja sample. The dominant taxa (with relative abundance $\geq 5\%$) were *Staurosirella pinnata* (Ehrenberg) Williams et Round (34.34%), *Achnantheidium minutissimum* (Kützing) Czarnecki (13.46%), *E. bonapartei* (12.06%), *Staurosira venter* (Ehrenberg) Grunow (7.66%) and *Pseudostaurosira brevistriata* (Grun.) Williams et Round (7.42%). Of the 26 taxa recorded in the Marić River sample, the dominant taxa were *A. minutissimum* (63.25%), *S. pinnata* (8.84%), and *Denticula tenuis* Kützing (7.63%). *E. bonapartei* was identified in low abundance (0.8%). In the Lake Sjenica sample, 61 taxa were identified, with *E. bonapartei* also found in low abundance (0.21%). High relative abundance was documented for taxa *Achnantheidium catenatum* (Bily et Marvan) Lange-Bertalot (39.12%), *A. gracillimum* (13.81%), *Fragilaria gracilis* Østrup (7.95%), *Nitzschia fonticola* Grunow (7.11%) and *Pantocsekiella costei* (Druart et F. Straub) K.T. Kiss et Ács (5.23%). In the October survey, 24 taxa were identified in the Lake Radoinja sample. The dominant taxa were *E. bonapartei* (38.24%), followed by *A. minutissimum* (30.77%), *Encyonopsis minuta* Krammer et Reichardt (9.45%) and *E. subminuta* (5.71%). A total of 71 taxa were identified in the Lake Zlatar sample. The most abundant taxa were *A. minutissimum* (16.48%), *E. bonapartei* (16.48%), *Amphora pediculus* (Kützing) Grunow (8.58%), *A. inariensis* (8.35%), *Diatoma ehrenbergii* Kützing (6.32%), and *Grunowia tabellaria* (Grunow) Rabenhorst (5.64%). In the October Lake Sjenica sample, 32 taxa were identified, with the dominant taxa being *Fragilaria crotonensis* Kitton (24.44%), *A. minutissimum* (17.94%), *A. catenatum* (11.21%), and *A. straubianum* (5.83%).

E. bonapartei was present in both seasons in Lake Radoinja samples, with a noticeable increase in relative abundance in October (38.24%) compared to August (12.06%). The Marić River sample contained the taxon in low abundance in August (0.8%), however it was not found in the October sample. In the Lake Sjenica August sample *E. bonapartei* was present with a low relative abundance (0.21%), which increased to 0.9% in October sample. In the Lake Zlatar sample, the species was present only in October, in high abundance (16.48%).

Physicochemical parameters

The water at the sampling sites was characterised by increased alkalinity, high conductivity and high dissolved oxygen, except at the Marić River in August, where the percentage of dissolved oxygen was significantly lower. The temperature was highest in August at Lake Sjenica and lowest in October at the Marić River. Lake Zlatar was surveyed only in October and showed similar physicochemical parameter values to the Marić River and Lake Radoinja, with slightly lower conductivity. Regarding nutrient concentrations, nitrite levels were very low across all sampling sites. Nitrate concentrations were also low, with the highest value measured in October at the Marić River. Ammonium concentration was elevated in August at Lake Sjenica, while showing low values at other sites. The highest concentrations of orthophosphates were measured in August at the Marić River, while the lowest were below the detection limit in October at Lake Radoinja (Table 2).

Table 2 Physicochemical parameters measured in the Marić River and Radoinja, Sjenica and Zlatar lakes

Sampling site	Marić River		Lake Radoinja		Lake Sjenica		Lake Zlatar	
Sampling month	August	October	August	October	August	October	August	October
T (°C)	/	10.0	20.9	13.0	23.3	14.6	/	14.1
O ₂ (%)	50.6	108.3	105.5	107.7	104.3	79.8	/	101.4
O ₂ (mg/L)	/	13.8	9.18	11.4	8.78	8.1	/	10.42
EC (µS/cm)	259.5	355	280	286	237.2	262	/	244.4
pH	7.75	8.32	8.42	8.29	8.64	8.37	/	8.73
NH ₄ ⁺ (mg/L)	0.03	0.03	0.02	0.03	0.82	0.04	/	0.02
PO ₄ ³⁻ (mg/L)	0.9	0.22	0.27	<0.06	0.25	0.21	/	0.39
NO ₂ ⁻ (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	/	<0.01
NO ₃ ⁻ (mg/L)	<0.08	0.54	0.11	0.39	<0.08	<0.08	/	0.17

Indicative ecological status assessment

In both the August and October surveys, the Marić River site showed an indicative ecological status of class I (“high”), while lakes Radoinja, Zlatar and Sjenica showed class II (“good”) (Table 3).

Table 3 Indicative ecological status based on the IPS and CEE diatom indices

Sampling site	Marić River		Lake Radoinja		Lake Sjenica		Lake Zlatar
Sampling month	August	October	August	October	August	October	October
IPS	16.2	18.6	15.6	17.6	17.2	17.1	17.0
CEE	15.7	17.6	16.4	17.3	15.6	17.8	16.6

DISCUSSION

The first occurrence of *E. bonapartei* in Serbia was documented only in the Marić River and Lake Zlatar, in 2021 study [11]. The taxon was very abundant in the August sample from Lake Zlatar (24.22%) and was absent in the October sample. At the same sampling site in the 2024 investigation, it was abundant in the October sample (16.48%) and was not found in August. In the 2021 samples from the Marić River, *E. bonapartei* was recorded in low abundance (2.39%) only in October, whereas in 2024, it was numerous in the August sample

(5.71%). During 2024, this diatom species was recorded at new localities: in samples from Lake Radoinja (situated downstream of Lake Zlatar), it was among the most abundant taxa, and in Sjenica Lake (situated upstream of Lake Zlatar), it was found in low abundances.

The dominant taxa recorded at the sampling sites of concern for this study can be found in a wide range of environmental conditions. Taxa *A. gracillimum*, *F. gracilis* and *E. subminuta* prefer oligotrophic, circumneutral waters [20,21], while *N. fonticola*, *D. ehrenbergii*, *D. tenuis* and *P. costei* can inhabit alkaline, oligo- to β -mesosaprobic habitats [22–24]. Benthic diatoms *A. catenatum*, *P. brevistriata* and *A. straubianum* tolerate meso- to eutrophic conditions [23,25,26]. A high tolerance range to pollution is characteristic of *A. minutissimum*, *F. crotonensis* and *A. pediculus* [20,27,28], while *E. minuta* is pollution sensitive [20,21]. In alkaline waters *S. venter* and *S. pinnata* are frequently found together, with *S. venter* occurring in waters of moderate conductivity and nutrient content [29], while *S. pinnata* is an indicator of moderate environmental stress [30]. *G. tabellaria* is found in medium to high electrolyte rich-habitats, predominantly artificial still waters [22].

The physicochemical parameters were within the expected ranges. Compared to the previous study [11], significantly increased concentrations of orthophosphates and ammonium were measured in the August 2024 sample of the Marić River. When compared to Heudre *et al.* [12], our measurements showed that *E. bonapartei* is present in waters with both lower and higher temperatures, as well as lower conductivity. The ecological status values did not significantly change from earlier investigations [11,31].

CONCLUSION

Three years after the first record of the diatom *E. bonapartei* in Serbia, it was again identified in the Uvac Special Nature Reserve, at two additional sampling sites: at Lake Radoinja and Lake Sjenica. At these reservoirs, species was not recorded in the earlier 2021 study. Additionally, its presence was confirmed at the original sampling sites – the Marić River and Lake Zlatar. The other dominant taxa mainly belong to the genera *Achnantheidium*, *Fragilaria*, *Encyonema*, *Diatoma*, *Staurosira*, *Staurosirella* and *Pseudostaurosira*. The physicochemical parameters showed expected values for the sampling sites. The determined ecological status classes were consistent with previous findings.

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